

**UNITED STATES APPLICATION**

**FOR**

**GRANT OF LETTERS PATENT**

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**FOR**

**UV DISINFECTION FOR WASTEWATER**

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# ULTRAVIOLET WASTEWATER DISINFECTION SYSTEM AND METHOD

## CROSS-REFERENCE TO RELATED APPLICATIONS

This non-provisional utility patent application claims the benefit of one or more prior filed co-pending non-provisional applications; a reference to each such prior application is identified as the relationship of the applications and application number (series code/serial number): The present application is a Continuation-In-Part of application 09/630245, which is incorporated herein by reference in its entirety.

## Background of the Invention

### (1) Field of the Invention

The present invention relates generally to a system and method for ultraviolet disinfection and, more particularly, to a system and method for ultraviolet disinfection of waste-containing fluids.

### (2) Description of the Prior Art

#### *Mechanism of Action*

It is well known in the art to use ultraviolet light (UV) for the disinfection treatment of water. Ultraviolet light, at the germicidal wavelength of 253.7 nanometers, alters the genetic (DNA) material in cells so that bacteria, viruses, molds, algae and other microorganisms can no longer reproduce. The microorganisms are considered dead, and the risk of disease from them is eliminated. As the water flows past the UV lamps in UV disinfection systems, the microorganisms are exposed to a lethal dose of UV energy. UV dose is measured as the product of UV light intensity times the exposure time within the UV lamp array. Microbiologists have determined the effective dose of UV energy to be approximately about 34,000 microwatt- seconds/cm<sup>2</sup> needed to destroy pathogens as well

1 as indicator organisms found in wastewater. Typical prior art disinfection systems and  
2 devices emit UV light at approximately 254 nm, which penetrates the outer cell  
3 membrane of microorganisms, passes through the cell body, reaches the DNA and alters  
4 the genetic material of the microorganism, destroying it without chemicals by rendering it  
5 unable to reproduce.

6 Ultraviolet light is classified into three wavelength ranges: UV-C, from about 200  
7 nanometers (nm) to about 280 nm; UV-B, from about 280 nm to about 315 nm; and UV-  
8 A, from about 315 nm to about 400 nm. Generally, UV light, and in particular, UV-C  
9 light is "germicidal," i.e., it deactivates the DNA of bacteria, viruses and other pathogens  
10 and thus destroys their ability to multiply and cause disease, effectively resulting in  
11 sterilization of the microorganisms. Specifically, UV "C" light causes damage to the  
12 nucleic acid of microorganisms by forming covalent bonds between certain adjacent  
13 bases in the DNA. The formation of these bonds prevents the DNA from being  
14 "unzipped" for replication, and the organism is unable to produce molecules essential for  
15 life process, nor is it able to reproduce. In fact, when an organism is unable to produce  
16 these essential molecules or is unable to replicate, it dies. UV light with a wavelength of  
17 approximately between about 250 to about 260 nm provides the highest germicidal  
18 effectiveness. While susceptibility to UV light varies, exposure to UV energy for about  
19 20 milliwatt-seconds/cm<sup>2</sup> is adequate to deactivate 99 percent of the pathogens.

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### Prior Art

Ultraviolet light has a proven track record of killing bacteria and viruses found in municipal wastewater. In addition, environmental concerns over the use of chemical disinfectants, coupled with improvements in ultraviolet-lighting technology, have led to the development of UV systems that treat spent metalworking fluids in the industrialized world; disinfect drinking water in developing countries; and clean aquaculture water, ballast water, and hospital air everywhere. Typically, chlorine gas or liquid is injected by a high-speed inductor directly into wastewater to kill bacteria before the water is discharged. According to industry experts, the main advantage of using UV instead of standard disinfection techniques is elimination of the transport and use of chlorine possible with the UV light-based system.

Unfortunately, evidence is mounting that organic chemical byproducts of chemical disinfection, especially byproduct of chlorination such as dioxane, are carcinogens and/or toxins for humans. Therefore, chemical disinfection is not a viable alternative when chemical purity of the fluid is desired and/or required. Additionally, in spite of this toxicological evidence, the EPA has recently been forced to relax restrictions on certain known carcinogenic chlorination by-product, such as chloroform. Additionally, other chemicals, such as the nitrate ion, have been shown to negatively influence the development of children.

In light of the emerging data concerning the toxicity of organic and inorganic chemicals and the relaxation of water purity regulations, reducing the discharge into the environment of these compounds is of growing concern. However, removal of these

1 compounds requires the use of extremely expensive methods, such as filtration through  
2 activated charcoal or similar. Thus, there exists a need for a system that can easily  
3 remove or eliminate organic and inorganic compounds from wastewater.

4       Used properly, ultraviolet light effectively destroys bacteria, viruses and other  
5 microorganisms in water and wastewater, without using chemicals. By doing away with  
6 chemical treatment, many other problems are also eliminated. There is no longer any  
7 need to worry about operator safety or the requirement for buildings for storage and  
8 handling of dangerous solutions and gases. Costly liability insurance premiums are  
9 significantly reduced. Testing of effluent for chlorine residual is no longer necessary, and  
10 toxicity problems associated with chlorine use are eliminated. Another factor leading  
11 municipalities to reconsider chlorination is its increased cost due to the national Uniform  
12 Fire Code adopted in 1993, which specifies expensive requirements for double  
13 containment of stored chlorine and chemical scrubbers in case of leaks.

14       Prior art applications of UV light used for disinfection of water include private  
15 drinking water supplies, municipal drinking water treatment plants, industrial product and  
16 process waters, and commercial applications, and wastewater treatment in primary,  
17 secondary, and tertiary treatment process for industrial, commercial and municipal  
18 wastewater treatment applications.

19       While UV purification is well suited for many residential, commercial, industrial  
20 and municipal water and wastewater treatment applications, considerations of the water  
21 quality and about the desired or required effluent purity impact the system design and  
22 performance. Prior art UV disinfectant systems work best when the water temperature is

2 interfere with the UV system performance.

9 Dr. George Tchobanoglous, presently of University of California at Davis.

9 these formulas referred to as “point source summation”.

23 time. As flows increase or higher UV doses are required, the multiple low-pressure lamp

1 concept becomes complex and cumbersome. The medium pressure UV lamp offers a  
2 solution to maintain simplicity and cost effectiveness in meeting the higher flow and  
3 higher dose challenge. A single medium pressure UV lamp can treat up to 2,300 gallons  
4 per minute of fluid. Notably, the UV disinfection systems and methods used by prior art  
5 consistently involve and teach the use of low pressure UV lamp and equipment for water,  
6 air and surface disinfection applications. These prior art systems require treatment  
7 chambers, usually constructed of stainless steel. The prior art air systems also use low-  
8 pressure UV lamps and treat air in storage tanks.

9 Where the prior art uses a medium pressure UV lamp, typically single lamp units  
10 are used, possibly capable of treating 10 to 2,300 gallons per minute of fluid. In these  
11 cases, prior art requires special enhanced medium pressure UV lamps, with these  
12 applications restricted for use treating high and low temperature fluids that are  
13 unachievable with low-pressure lamps. Even with such configurations, the use of  
14 immersion-positioned UV lamps in an effective chamber design still requires system  
15 downtime to change the UV lamp. Special enhanced UV lamp design is required to  
16 achieve the highest performance in TOC reduction, ozone removal and chlorine  
17 destruction.

18 Problems exist for prior art systems where factors are present that inhibit UV light  
19 from penetrating the water. Turbidity, which is the state of water when it is cloudy from  
20 having sediment stirred up, interferes with the transmission of UV energy and decreases  
21 the disinfection efficiency of the UV light disinfection system. In cases where the water  
22 has high iron or manganese content, is clouded and/or has organic impurities, it is usually  
23 necessary to pre-treat the water before it enters the UV disinfection stage because

1 deposits on the quartz-encased UV lamps, which are immersed in the water to be treated,  
2 interfere with the UV light transmission, thereby reducing the UV dose and rendering the  
3 system ineffective. Prior art typically employs UV purification in conjunction with  
4 carbon filtration, reverse osmosis and with certain chemicals to reduce fouling between  
5 cleanings of the quartz sleeves that surround the UV lamps.

6 Typically, prior art devices and systems for disinfecting water via ultraviolet light  
7 exposure commonly employ standard ultraviolet light sources or lamps encased in quartz  
8 sleeves and suspended in the water being treated. Benefits of using ultraviolet light for  
9 disinfecting water, particularly waste water treatment, include the following: no  
10 chemicals, like chlorine, are needed to ensure effective water disinfection provided that  
11 the proper number of lamps are used and properly positioned for a given influent and  
12 flow rate; since no chemicals are required in the disinfection process, no storage and/or  
13 handling of toxic chemicals is required; no heating or cooling is required to ensure  
14 disinfection; no storage tanks or ponds are necessary because the water can be treated as  
15 it flows through the system; no water is wasted in the process; no change in pH, chemical  
16 or resistivity of the water being treated; approximately at least 99.99% of all waterborne  
17 bacteria and viruses are killed via UV light exposure for disinfection; thereby providing  
18 increased safety of using the system and effectiveness of same.

19 As set forth in the foregoing, prior art UV water treatment systems disinfect and  
20 remove microorganisms and other substances from untreated, contaminated water sources  
21 and produce clean, safe drinking water. The core technology employed in WaterHealth  
22 International's system is includes a patented, non-submerged UV light. This technology  
23 is claimed by WHI to be a recent and tested innovation developed at the Lawrence



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1 Berkeley National Laboratory, a premier, internationally respected laboratory of the U.S.  
2 Department of Energy managed by the University of California. This prior art system  
3 delivers a UV dose of up to 120 mJ/cm<sup>2</sup>, which is more than three times the NSF  
4 International requirement of 38 mJ/cm<sup>2</sup> and exceeds World Health Organization and  
5 EPA water quality standards and effectively treats bacteria, viruses and *Cryptosporidium*  
6 in drinking water. In addition, recent research conducted at two different laboratories  
7 indicates that UV doses of 10 mJ/cm<sup>2</sup> or less produce 4-log reductions in *Giardia*. Based  
8 on this research, UV dosage of up to 120 mJ/cm<sup>2</sup> greatly exceeds the dosage required for  
9 inactivation of *Giardia*. Additional components included in WaterHealth International's  
10 systems effectively treat specific problems such as turbidity, silt, tastes, odors and various  
11 chemicals. Significantly, WHI's systems are not intended to treat raw sewage or  
12 wastewater.

13 Among applications for UV disinfection systems for water include wastewater  
14 treatment and surface treatment. By way of example and explanation, disinfection of  
15 municipal wastewater using UV light avoids problems associated with storage, transport  
16 and use of chemicals and associated regulation for them. UV disinfection is safe, cost  
17 effective and applicable to tertiary treated effluent as well as secondary, primary, and  
18 combined sewer overflows (CSO) and storm water. Ultraviolet light can help improve  
19 shelf life of products and allow processors to reduce chemical additives in wash water  
20 without sacrificing high levels of disinfection. UV light provides non-chemical microbial  
21 control for captive water loops without altering the taste, color or odor of the food.  
22 Environmentally safe UV disinfection is one of the few water treatment methods

1 unburdened by regulatory restrictions, consumer/environmental group concerns or high  
2 operation costs.

3 By way of comparison between prior art UV disinfection systems and traditional  
4 chlorine-based disinfection, the commercially available Trojan UV system can disinfect  
5 more consistently and effectively than is possible with current chlorination procedures,  
6 with significantly less cost per gallon. The UV treatment takes approximately 6-10  
7 seconds in a flow-through channel, while chlorine requires 15-20 minutes treatment time  
8 in a contact tank. According to Trojan literature, UV disinfection can greatly reduce  
9 capital and operating costs. With UV treatment, it is possible to eliminate the need for  
10 large contact tanks designed to hold peak flows. Space requirements are reduced and no  
11 buildings are needed since the entire process and related commercially available  
12 equipment are designed to operate outdoors.

13 However, cleaning and maintenance of the quartz sleeves, which are necessary  
14 and essential to protect the UV lamp or light source used in nearly all prior art systems,  
15 can become a time-consuming duty, especially when working with multi-lamp low  
16 pressure systems. During operation while the UV lamps and quartz sleeves are  
17 suspending in the water to be treated, minerals and contaminants in the water deposit  
18 onto the quartz sleeves, thereby causing fouling on the sleeve surface. This fouling  
19 reduces the effectiveness of the UV lamps because the fouling interferes with the UV  
20 light transmission into the water. To save time and prevent quartz sleeve fouling a  
21 cleaning mechanism can be supplied for either manual or automatic operation, like using  
22 wiper glides over the sleeves to remove deposits, which may block the light emitted from  
23 the UV lamp. This provides improved performance and reduces maintenance time, but



1 borne chemicals and the UV light source requires less maintenance and cost than prior art  
2 systems and devices while providing at least the same disinfection level for a given  
3 influent and flow rate thereof.

4 One object of the present invention is to provide a UV disinfection system for  
5 treating waste-containing fluids configured and arranged to function effectively with at  
6 least one UV light source or lamp that is not submerged in the fluid to be disinfected.  
7 The UV light source is positioned outside the fluid to be disinfected via exposure to at  
8 least one UV dose zone wherein UV light is projected into the zone.

9 Another object of the present invention includes presentation of the UV light  
10 source presented in at least two primary configurations: a vertical riser configuration and  
11 a planar or horizontal configuration. In the vertical riser configuration the UV light  
12 source is positioned above the waste-containing fluid to be treated and projecting a UV  
13 dose zone downward toward and into the waste-containing fluid to be treated, with the  
14 waste-containing fluid moving upward toward the UV light source. Alternatively, the  
15 UV light source may be presented in a planar or horizontal design, wherein the UV light  
16 source is positioned above the waste-containing fluid to be treated and projecting a UV  
17 dose zone downward toward and into the waste-containing fluid to be treated, with the  
18 waste-containing fluid moving in a direction substantially perpendicular to the UV dose  
19 zone.

20 Still another object of the present invention is to provide a UV dose zone  
21 including at least one zone, more preferably four zones, wherein one zone includes an  
22 interface zone positioned between the UV light source and the fluid to be treated and  
23 another zone includes a reaction zone positioned within the fluid. The reaction zone may

1 be formed by an interface plate that incorporates catalytic properties to enhance desired  
2 reactions.

3 The present invention is further directed to a method for treating waste-containing  
4 fluids by disinfecting those waste-containing fluids using UV light projected by at least  
5 one UV light source producing at least one dose zone, the UV light source being  
6 positioned outside the waste-containing fluid.

7 Accordingly, one aspect of the present invention is to provide a system and  
8 method for disinfecting waste-containing fluid including at least one UV light source  
9 positioned outside the waste-containing fluid to be treated with the at least one UV light  
10 source producing at least one UV dose zone for disinfecting the waste-containing fluid.

11 Another aspect of the present invention is to provide a system and method for  
12 disinfecting and purifying fluid including at least one UV light source positioned outside  
13 the fluid to be treated with the at least one UV light source producing four UV dose zones  
14 for disinfecting the fluid, with one zone provided at an interface zone, and one zone  
15 provided at a reaction zone positioned between the UV light source and the fluid to be  
16 treated. The reaction zone may be formed by an interface plate that incorporates catalytic  
17 properties to enhance desired reactions

18 Still another aspect of the present invention is to provide a system and method for  
19 disinfecting waste-containing fluid including at least one UV light source positioned  
20 outside the waste-containing fluid to be treated with the at least one UV light source  
21 producing at least one UV dose zone for disinfecting the waste-containing fluid, wherein  
22 the at least one UV light source is a medium-to-high intensity UV light source or spectral  
23 calibration lamp.

These and other aspects of the present invention will become apparent to those skilled in the art after a reading of the following description of the preferred embodiment when considered with the drawings.

#### Brief Description of the Drawings

Figure 1 is an illustration of **PRIOR ART** in a side view.

Figure 2 is an illustration of a side view of a UV disinfection system constructed according to the present invention in a vertical riser configuration.

Figure 3 is an illustration of an exploded side view of the embodiment shown in Fig. 2.

Figure 4 shows an illustration of a UV disinfection system of an alternative embodiment of the present invention.

Figure 5 is an illustration of an exploded side view of the embodiment shown in Fig. 4.

Figure 6 is an illustration of the UV dose zones generated in a vertical riser configuration.

Figure 7 is an illustration of the UV dose zones generated in an alternative embodiment of the present invention.

#### Detailed Description of the Preferred Embodiments

In the following description, like reference characters designate like or corresponding parts throughout the several views. Also in the following description, it is to be understood that such terms as "forward," "rearward," "front," "back," "right," "left," "upwardly," "downwardly," and the like are words of convenience and are not to be construed as limiting terms.

Referring now to the drawings in general, the illustrations are for the purpose of describing a preferred embodiment of the invention and are not intended to limit the invention thereto. Figure 1 shows a prior art system for ultraviolet (UV) disinfection of a

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1 of the lamp assembly 300, thereby focusing, directing, and controlling the light ray output  
2 350 that irradiates the fluid 210 and that sterilizes any microorganisms that exist in the  
3 fluid 210. The UV light ray output 350 irradiates and may also be transmitted through  
4 the fluid 210. UV light ray output 350 that is transmitted through the fluid and strikes the  
5 reflective interior surfaces (not shown) of the VRC components is reflected back into the  
6 fluid where it may strike microorganism. The reflection of the UV light ray output 350  
7 back into the fluid by the reflective interior surfaces of the VRC components enhances  
8 the killing capacity of the VRC system 200.

9 Additionally, the interface plate may possess catalytic properties such that certain  
10 reactions are catalyzed in the vicinity of the interface plate. For example,  $\text{TiO}_2$  may be  
11 incorporated into the interface plate that is made of glass or other appropriate material.  
12 When such a plate is irradiated with UV light, fatty acids and other organic chemicals are  
13 chemically reduced, resulting in degradation to smaller volatile products such as  
14 methane, ethane, etc. Additionally, nitrate ion is reduced to elemental nitrogen in such a  
15 system. Thus, the incorporation of  $\text{TiO}_2$  into the interface plate with subsequent UV  
16 irradiation reduces the levels of two potential human toxins – organic chemicals and  
17 nitrate ion. The interface plate may also perform mechanical or other physical functions.  
18 For example, the plate may grind and/or sift particles contained within the fluid. The  
19 plate may also provide cooling, heat, steam, or gas(es) to the reaction zone to enhance  
20 desired reactions or inhibit undesired reactions. Heat, steam, or other gases may also be  
21 added in order to increase the vapor zone. In general, the interface plate can be used to  
22 facilitate surface reactions and/or surface/air reactions.



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1 non-submerged UV light source system and the hydraulic system. The light source  
2 system includes a housing surrounding and supporting a UV light source or lamp having  
3 at least one optical component positioned and arranged to direct the UV light rays toward  
4 and through an output, thereby introducing UV light rays toward a waste-containing fluid  
5 for disinfection of the fluid.

6 The hydraulic system includes a hydraulic tube and pumping system for forcing  
7 the waste-containing fluid upward through the tube toward the light source(s). The present  
8 invention includes the use of hydraulic systems that comprise a transporter or pumping  
9 system, and at least one interface plate. The hydraulic system serves at least three  
10 functions: it carries wastewater influent to an interface and provides flow to at least one  
11 interface plate and discharges the treated influent water as effluent to rivers or streams.  
12 The VRC system may include quick-connect lamps and housings with a monitoring and  
13 indicator system that would indicate that a lamp had failed. Each riser may have an  
14 individual, dedicated lamp and optical system with overlap between neighboring lamps to  
15 eliminate dead zone. Each riser in the VRC system may also have a valve that shuts off  
16 the riser in case of failure.

17 Advantageously, these systems have several UV dose zones established within  
18 them. In the VRC system, as best shown in Figs. 3 and 5, the UV light source 310 is  
19 positioned within a UV light source system 300, including optical components as  
20 previously described, above the fluid to be treated and projecting a UV dose zone  
21 downward toward and into the fluid to be treated, with the fluid moving from the influent  
22 point 120, flowing vertically up the interior pipe 220 toward the UV light source 310, and  
23 then exiting the interior pipe 220 through the interface plate 240. The at least one UV



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10           The last zone is the submerged UV dose zone 540, which creates a variable UV  
11   dose zone that decreases in effectiveness at greater distances from the UV light source.

For the generally static non-riser configuration, the zones are different than those described in the VRC system. In the generally static non-riser system, generally shown as 600 in Fig. 7, the first zone is the light source system exit UV dose zone 610, which occurs at the light source system and air interface. Then next zone is the air UV dose zone 620, which occurs just beneath the UV light source and just above the water surface 230. The next zone is the vapor zone, which occurs just above the surface of the water. The last zone is the submerged UV dose zone 640, which creates a variable UV dose zone that decreases in effectiveness at greater distances from the UV light source.

For the planar configuration, the zones are different than the VRC and reservoir configurations. Several UV dose zones are established within the system (not shown). The first zone is the air UV dose zone that occurs just beneath the UV light source and just above the water. The next zone is the air/water interface UV dose zone that occurs at

1 the air and water interface. The last zone is the submerged UV dose zone, which occurs  
2 within the flowing water.

3 While generally regarding the UV light source and configuration thereof, the  
4 preferred embodiment of the present invention includes at least one optical component  
5 positioned between the UV light source and the UV light source system output point.  
6 Advantageously, the use of optical components enables the system to maximize the  
7 intensity, focus, and control of the UV light rays at the output for any given UV light  
8 source or lamp. Also, optical components, including but not limited to reflectors,  
9 shutters, lenses, splitters, mirrors, rigid and flexible light guides, homogenizer or mixing  
10 rods, manifolds and other couplers, filters, color wheels, and the like, can be utilized in  
11 combination to achieve the desired control and output, as set forth in U.S. patent numbers  
12 6,027,237; 5,917,986; 5,911,020; 5,892,867; 5,862,277; 5,857,041; 5,832,151; 5,790,725;  
13 5,790,723; 5,751,870; 5,708,737; 5,706,376; 5,682,448; 5,661,828; 5,559,911; D417,920  
14 and co-pending applications 09/523,609 and 09/587,678 which are commonly owned by  
15 the assignee of the present invention, and which are incorporated herein by reference in  
16 their entirety. Additionally, optical component such as gratings, dichroic filters,  
17 focalizers, gradient lenses, and off-axis reflectors may be used.

18 With regard to light guides, these may be fiberoptic lines composed of acrylic,  
19 glass, liquid core, hollow core, core-sheath, or a combination.

20 With regard to lenses, several embodiments are envisioned. Imaging lenses, such  
21 as a parabolic lens, and non-imaging lenses, such as gradient lenses, may be used. A  
22 gradient lens collects light through a collecting opening and focuses it to an area smaller  
23 than the area of the collecting opening. This concentration is accomplished by changing






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1 commonly mercury (Hg), can be used with the system configuration according to the  
2 present invention, depending upon the fluid or influent characteristics and flow rates  
3 through the system. Furthermore, while high and ultra high pressure lamps have not been  
4 used commercially to date by any prior art system, predominantly because of the low  
5 energy efficiency associated with them and the lack of capacity for prior art design and  
6 configuration formulas to include high pressure UV lamps, the present invention is  
7 advantageously suited to accommodate medium to high to ultra high pressure lamps. In  
8 particular, a preferred embodiment according to the present invention employs medium to  
9 high-pressure UV lamps, more preferably high-pressure UV lamps. The present  
10 invention is advantageously suited to accommodate medium to high to ultra high pressure  
11 lamps, all of which can be metal, halogen, or a combination metal halide. Additionally,  
12 spectral calibration lamps, electrodeless lamps, and the like can be used.

13 In particular, a preferred embodiment according to the present invention employs  
14 a pencil-type spectral calibration lamp. These lamps are compact and offer narrow,  
15 intense emissions. Their average intensity is constant and reproducible. They have a  
16 longer life relative to other high wattage lamps. Hg (Ar) lamps of this type are generally  
17 insensitive to temperature and require only a two-minute warm-up for the mercury vapor  
18 to dominate the discharge, then 30 minutes for complete stabilization.

19 A Hg (Ar) UV lamp, which is presently commercially available and supplied by  
20 ORIEL Instruments, is used in the preferred embodiment according to the present  
21 invention. The ORIEL Hg(Ar) lamp, model 6035, emits UV radiation at 254 nm. When  
22 operated at 15 mA using a DC power supply, this lamp emits 74 microwatt/cm<sup>2</sup> of 254  
23 nm radiation at 25 cm from the source.



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UV Systems, Inc. The fusion lamp is a preferred lamp for a planar vertical riser system configuration, according to the present invention, to provide fast flow rates of the fluid treated within the system. This fusion lamp has a spectrum like a low-pressure lamp, having very strong UVB&C availability and output, but is a high power lamp having approximately 200W/cm. Significantly, as set forth in the foregoing, no prior art teaches or suggests the use of high pressure lamps, in fact, all standard formulas, including those developed by Dr. George Tchobanoglous, for system design and operation use low pressure lamps.

Surprisingly, the attached data supporting the novelty and non-obviousness of the present invention shows that the UVB&C efficacy for a high-pressure lamp is about 7-8%, compared to about 20-21% for a Germicidal lamp, and about 5% for a medium pressure lamp. Thus, one Fusion lamp would replace about 40 germicidal lamps or about 20 medium pressure lamps by the following analysis:

$$\frac{[\# \text{ lamps of type } x]}{[\# \text{ lamps of type } y]} = \frac{[P/L(\text{type } y)] * [\text{Efficacy}(\text{type } y)]}{[P/L(\text{type } x)] * [\text{Efficacy}(\text{type } x)]}$$

$$6 \quad [\# \text{ MPL}] / [\# \text{ HPL}] \sim [200 * 8\%] / [20 * 5\%] \sim 20$$

7     $[\# \text{ LPL}]/[\# \text{ HPL}] \sim [200*7\%]/[2*21\%] \sim 40$

Therefore, instead of having a facility with at least about 11,500 ea. 300 W MPLS as with prior art UV water disinfection systems, the present invention uses only a few hundred UV high-pressure lamps (HPL), depending on details of the design for a specific influent composition and flow rates desired for a given system. These results are surprising and not supported by prior art systems or the formulas used to design and configure them for effective operation. A variety of tubular lamp types may be used according to the present

1 invention: Low Pressure (Power) germicidal Lamps (LPL), Medium Pressure (Power)  
2 Lamps (MPL), and Ultra-High Power Lamps (UHPL), to be used with water of various  
3 purity levels requiring differing dosing (Joules/liter) for disinfection, the surprising  
4 results supporting the use of medium to high pressure UV lamps for the UV disinfection  
5 system for water, according to the present invention, are established.

6 An additional advantage of high-power lamp systems is that extra-UV  
7 wavelengths, when delivered at sufficient intensity, may destroy or otherwise inactivate  
8 microorganisms as well. Several mechanisms of action are possible, but in general, the  
9 high-dose light denatures cell components such as proteins, cell membranes, and the like  
10 and inactivates the microorganism.

11 Additional considerations for a UV disinfectant system and method for treating  
12 water are installation cost, and lamp life. The lamp life for the Fusion lamp is  
13 approximately about 5000 hours, which is comparable to the low pressure lamps (LPL)  
14 and comparable to the life of the medium pressure lamp (MPL). The installation cost of  
15 the Fusion lamp is somewhat higher, but the maintenance and associated costs for  
16 operation is lower, thereby providing an overall lower cost system when compared with  
17 the prior art systems.

18 The system according to the present invention uses medium to high pressure UV  
19 lamps configured and functioning above the fluid or water flow. With this system, the  
20 number of lamps necessary to treat a given influent and flow rate can be reduced by  
21 perhaps a factor of ten, which is a major advantage in practical application. Also, the  
22 lamps are not susceptible to fouling, since they are not immersed in the waste-containing  
23 fluid to be disinfected. Additionally, the design of the present invention allows for a

1 significant reduction in heat in the water. Furthermore, the maintenance and servicing is  
2 greatly simplified. Also, in the vertical riser configuration according to one preferred  
3 embodiment configuration, the reactor design, which would comprise a number of  
4 cylindrical tubes oriented vertically, includes a hydraulic system having pumping  
5 equipment and a significant amount of pumping power.

6 The present invention advantageously includes all of the above features, in  
7 particular because the UV lamps are separated from the flow stream and include a fiber  
8 optic delivery system, as well as using multi-kiloWatt lamps, like the Vortek Ultra-High  
9 Power Discharge (UHPD) lamps or similar commercial equivalent. The power range for  
10 these lamps is in the 10's of kiloWatts to MegaWatt range. Their geometry is  
11 cylindrical, like the medium power lamps, but they are roughly 1000 times more  
12 powerful. Advantageously, this lamp provides a much simpler facility, wherein servicing  
13 and maintenance are much easier and less frequently performed.

14 The flexibility of the UV waste-containing fluid disinfection system according to  
15 the present invention makes it possible to use lamp configurations similar to prior art  
16 systems for the overall geometry. However, the use of a much higher power lamp is  
17 preferred, thereby reducing the water treatment facility complexity and costs. This novel  
18 combination of higher pressure and power UV light sources in the present invention  
19 creates surprising results, even where prior art system configurations, i.e., horizontal  
20 flow-type configurations, are employed. Furthermore, the use of optical components  
21 within the UV light source system to focus, control, and increase the output intensity of  
22 the UV light rays introduced to the fluid to be disinfected increases the overall  
23 effectiveness of the present invention, even where the retrofit geometry is employed.

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1        Thus, the present invention can be configured effectively either similarly to prior  
2 art-like system or retrofit geometry, i.e., a configuration of lamps above a horizontal flow  
3 stream while still surprisingly employing novel and non-obvious elements like UHPL and  
4 HPL in combination therewith, or in a clear departure and in complete differentiation  
5 from all prior art systems for all water treatment, having a configuration comprising the  
6 vertical riser geometry as shown in Figure 2, including having at least one interface plate.  
7 In the retrofit geometry or configuration, there is a turbulence-inducing foil immersed in  
8 the flow stream below each lamp to assure that sufficient mixing occurs, thereby ensuring  
9 exposure of all of the microorganisms within the waste-containing fluid to the UV dose  
10 zone such that those microorganisms are sterilized. However, the use of the vertical riser  
11 configuration creates even more surprising results in that a multiplicity of UV dose zones  
12 are created as the fluid to be treated is forced via a hydraulic system toward the UV light  
13 source system, including UV light source or lamp and optical component(s).

14        Two main types of lamps are embodied according to the present invention for use  
15 therein as at least one light source for a given configuration. In particular, a tubular lamp  
16 is generally approximately about 1000 mm long, and between about 30 to about 60 mm  
17 diameter. A fusion lamp produces UV light output at about 250 mm and is  
18 approximately about 8 mm diameter in the middle and approximately about 14 mm  
19 diameter near the ends of the lamp. Alternatively, a high power, short arc (HP-SA) lamp  
20 figure is preferred in other configurations. Significantly, alternative lamp embodiments,  
21 including but not limited to alternative lamp design, power, and UV output efficiencies,  
22 and reasonable equivalents thereof may be substituted for these lamps identified herein as

1 preferred embodiments without departing from the scope and teachings of the present  
2 invention.

3 Characteristics of and advantages to the present invention include at least the  
4 following: the use of Ultra High Power Lamps reduces complexity of illumination  
5 system, the lamps are isolated from the flow stream eliminating the fouling problem,  
6 since the UHPL, e.g., Vortek lamps, are immersed in their own flowing water cooling  
7 jackets (purified water), much of the heat will be dissipated in the Vortek-type lamp  
8 cooling system, probably eliminating the need for the heat-rejecting cold mirrors, since a  
9 much smaller number of parts are used (most likely less than 1% of the parts), the  
10 servicing costs are likely to be much lower. If the lamp life is longer for a given system  
11 constructed according to the present invention, the servicing costs are reduced by a  
12 similar factor as well.

13 The present invention allows a significantly simplified system, potentially  
14 significantly lower operating costs, and the capacity to process large quantities of water  
15 as well as relatively small quantities, as for home use. For a single-dwelling system, a  
16 single vertical riser UV light source system, is constructed and configured to be attached  
17 to the treated wastewater discharge. In this system, the UV light source is positioned  
18 within a UV light source system, including optical components, above the fluid to be  
19 treated and projecting a UV dose zone downward toward and into the fluid to be treated,  
20 with the fluid moving from the influent point, flowing vertically toward the UV light  
21 source, and then exits the effluent point. The at least one UV light source is positioned  
22 above the fluid to be treated and projecting UV light rays downward toward and into the  
23 fluid to be treated, with the fluid moving upward toward the UV light source. Several

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1 microorganism build-up in the reservoir. For completion of the system, a single vertical  
2 riser UV light source system is constructed and configured to be attached to the reservoir  
3 system. In this system, the UV light source is positioned within a UV light source  
4 system, including optical components (not shown), above the fluid to be treated and  
5 projecting a UV dose zone downward toward and into the fluid to be treated, with the  
6 fluid moving from the influent point (reservoir effluent point), flowing vertically toward  
7 the UV light source, and then exits the effluent point. The at least one UV light source is  
8 positioned above the fluid to be treated and projecting UV light rays downward toward  
9 and into the fluid to be treated, with the fluid moving upward toward the UV light source.  
10 Several UV dose zones are established within the system. The first zone is the light  
11 source system exit UV dose zone, which occurs at the light source system and air  
12 interface. Then next zone is the air UV dose zone which occurs just beneath the UV light  
13 source and just above the water and the at least one interface plate. The next zone is the  
14 interface plate UV dose zone which occurs at the intersection of the water and the at least  
15 one interface plate. The at least one interface plate is used to provide a surface zone for  
16 UV disinfection above the fluid and to provide additional treatment means for balancing  
17 pH, affecting effluent chemistry, providing a catalyst, and the like. The last zone is the  
18 submerged UV dose zone, which creates a variable UV dose zone that decreases in  
19 effectiveness at greater distances from the UV light source.

20 The foregoing described the general features of selected UV water disinfection  
21 system applications, including wastewater treatment, other water purification, e.g.,  
22 drinking water, and the like, for permanent or fixed-system installations and

1 configurations. However, the present invention is also useful for application in a portable  
2 water disinfection system.

3 The following provides an alternate embodiment that includes selected desirable  
4 features of the present invention. There are a number of very high power tubular lamps  
5 that may be employed in another embodiment for UV light source system and hydraulic  
6 system combinations. The medium pressure lamps could be used, albeit at a much higher  
7 power level that was indicated for the commercially available Trojan Tech design  
8 (300W). Medium pressure lamps are available in the multi-kiloWatt range. The high  
9 power lamps, e.g., Vortek lamps, are a desirable source since they have strong UV  
10 emission, and are available in the 100's of kW to MegaWatt range.

11 In one embodiment, the water flow is in a horizontal channel or direction, which  
12 does not require all of the vertical riser components, like the interface plate and some  
13 hydraulic components. However, optical components are desirably included in the planar  
14 or horizontal (also referred to as retrofit) designs. The water turbulence could be achieved  
15 by having horizontal "foils" (like those on the trailing edge of an airplane wing),  
16 immersed in the flow channel. These foils would make a shallow turbulent region in the  
17 flow channel allowing good exposure of the infected water past the lamps. In this simple  
18 way, the function of the complex vertical riser would be achieved, with much fewer parts.

19 Thus the configuration includes a number of cylindrical or tubular light sources or  
20 lamps oriented and arranged in a horizontally spaced-apart distance from each other in a  
21 non-submerged configuration over a flowing fluid stream, with each lamp having a foil  
22 positioned approximately directly under it to provide the turbulent flow mixing desired.

The fundamental physical parameters that control the design for these compact/short arc kinds of systems according to the present invention include: the lamp power per unit length [P]; the Cylindrical Riser flow tube Cross-section[A]; the dosing required [D] where  $D = \text{Energy/volume}$ , and the flow rate & dwell time. For the purposes of this analysis the cell widths are between about 10 cm and about 15 cm, the water penetration approximately about 10 cm. The dwell time depends on the effectiveness of the turbulent mixing, the influent characteristics, and type of contamination.

A cylindrical riser for cell of 10 to 15 cm diameter as being a practical size, thereby providing a disinfection dosage,  $D = \text{Energy/volume} = E/V$  which varies from about 50 J/liter to perhaps 500 J/liter.

The three parameters T, P/A, and D control the possible/practical flow geometries. Since  $P/V = E/V/T$  where P= input power, E= input energy, V = volume of water being processed & T = dwell time, then  $P/[A*d] = D/T$

where  $D = E/V$ , the input energy/volume, or dosing

Then,  $T = D*d/[P/A]$

$T = D(\text{J/liter}) * d(\text{cm}) * (1 \text{ liter}/1000\text{cm}^3) / [P/A(\text{W}/\text{cm}^2)]$ .

Further,  $P/A = P/[\pi * \text{dia} * \text{dia}/4] \sim 3000/[3.14 * 10 * 10/4] \sim 38 \text{ W}/\text{cm}^2$  for 3000W Hg, & a 4" diameter vertical riser configuration.

$P/A \sim 20000/[3.14 * 15 * 15/4] \sim 113 \text{ W}/\text{cm}^2$  for Xe & a 6" dia riser

TABLE 1

Dwell Time for Compact/Short-arc Mercury and Xenon Lamps					
		Dose (J/l)			
Lamp type V	Wattage	50	100	200	500
Mercury 40W/cm <sup>2</sup>	40	0.013	0.025	0.050	0.125
Xenon 100W/cm <sup>2</sup>	100	0.005	0.010	0.020	0.050

Surprisingly and significantly, these dwell times are much shorter than understood or set forth and commonly accepted and used within prior art. If the lamp power is reduced to 10%, and increase the cell diameter 2x, the results of Table 2 exist (SEE BELOW).  
 $P/A = P/[\pi \cdot \text{dia} \cdot \text{dia}/4] \sim 300/[3.14 \cdot 15 \cdot 15/4] \sim 1 \text{ W/cm}^2$  for 300W Hg, & a 6-inch diam. riser; also  $P/A \sim 2000/[3.14 \cdot 30 \cdot 30/4] \sim 2.8 \text{ W/cm}^2$  for Xe & a 12-inch diam. riser

TABLE 2

Dwell Time for Compact/Short-arc Mercury & Xenon Lamps					
		Dose (J/l)			
Lamp type V	Wattage	50	100	200	500
Mercury 1W/cm <sup>2</sup>	1	0.500	1.000	2.000	5.000
Xenon 2.5W/cm <sup>2</sup>	2.5	0.200	0.400	0.800	2.000

Note that the dwell times are up to about a second if the irradiance is reduced by about a factor of 40, for example by reducing the lamp power to 10%, and increasing the cell diameter by x2 to 8" and 12" respectively. These are fairly large cells with low

power lamps, so it would take a lot of these to process very much water per day, making  
their economic practicality more questionable.

For high power density processing cells, the dwell time is much shorter than the between about 6-second to about 10-second dwell time indicated in the foregoing. In order to get dwell times of between about 6 seconds to about 10 seconds, the lamp power must be less than 10% of the kilowatt levels selected or predetermined, and the cell diameters must be correspondingly much larger, e.g., up to 3x larger diameter. Those numbers would not be very consistent with the geometry of the short/compact arc lamp cylindrical risers; as such, the range of possible and feasible configurations for the system according to the present invention is flexible to accommodate a variety of lamp types and powers.

A main factor for consideration with respect to arc lamp spectra is the percentage of UV light output found in approximately the disinfection wavelength region, namely UVB&C from between about 200 to about 300 nm. The UV light sources contemplated within the scope of the present invention indicate that the peak of the disinfection effect occurs at about 265 nm. Also, the UV light available for disinfection effect is reduced gradually on the short wavelength side, and rapidly on the long wavelength side.

Notably, low-pressure mercury (Hg) arc lamps are efficient radiators in the UVB&C bands due to a resonant emission at about 254 nm. Advantageously, this is close to the optimum UVC wavelength for disinfection of the fluid. Generally, the total emission of radiation by a low-pressure tubular, germicidal lamp is about 20 to 35%, depending on the design and operating parameters (the rest of the power being consumed to heat the electrodes and the bulb) with 80 to 90% in about the 254 nm wavelength.

1 Thus, UVC efficacy is about 20 to 30%. The other principle line is at 365 nm, which is  
2 outside the disinfection range. In some bulb designs it is the 365 nm line that dominates,  
3 and the disinfection effect will be substantially reduced.

4 At low pressure, the plasma that forms the arc is in the "glow regime," which is  
5 characterized by high electron temperatures, and much lower ion and neutral gas  
6 temperatures (typically  $T_e \sim 10,000\text{K}$ ,  $T_i \sim T_g \sim 500\text{K}$ ). Under these conditions, the plasma  
7 is optically transparent, and a few, very narrow emission "lines" characterize the  
8 spectrum. Here, the emissivity will be low  $< 0.1$ .

9 As the plasma temperature and density is increased (requiring higher current), the  
10 arc temperature increases. The plasma becomes optically thick, and the electron, ion and  
11 neutral gas temperature become comparable. The spectrum becomes characterized by a  
12 blackbody continuum with a few lines superposed on it. A rule of quantum physics is  
13 that the peak of the lines must be below the blackbody curve for that temperature, so a  
14 blackbody curve can be fit to the peaks of the lines to deduce the effective arc  
15 temperature, but the bulk of the emission will be from the continuum under the lines.

16 As an example, consider the high pressure Argon, commercially available Vortek  
17 lamp. This lamp is a high pressure Argon arc operated at very high loading ( $P_{in}/L$ ). To  
18 be specific, consider the 100 kW lamp. The length is 20 cm, so the loading is 5 kW/cm.  
19 The radiated output is given as 40 kW, 2 kW/cm so the efficiency is 40% (other Vortek  
20 lamps are up to, and perhaps exceeding 50% radiative efficiency. The spectrum indicates  
21 a peak at 800 nm which corresponds to an arc temperature deduced from Wien's law  
22  $(2898\text{K}/W_{\max}(\mu\text{m})) = T(\text{K})$  of  $\sim 3600\text{K}$  (the quoted figure is 3800K). Calculating the

1 blackbody emission from the arc with diameter 1.1 cm at 3800K, the result gives 1.8  
2 kW/cm with emissivity of 0.4.

3 The UVB&C emission of the Vortek 100 kW lamp rises almost linearly from 200  
4 to 300 nm. Thus, the UVB&C efficacy is about 5 %, and the UVB&C emission is about  
5 5 kW. Notably, this is near the blackbody limit for a higher temperature (6500K). The  
6 low emissivity occurs through the visible and NIR spectrum. Additionally, the lamps  
7 emit about 5% UVB&C-200 to 300 nm, 10% UVA300-400 nm, 30% visible-400 to 700  
8 nm, and 50% NIR at 700 to 1400 nm). However, the results are affected by arc  
9 temperature; the results set forth herein are associated with low arc temperature. As the  
10 arc temperature is increased, the amount of UVB&C increases dramatically, e.g., if the  
11 arc temperature is increased to 8600K, the UVB&C efficacy increases to 20%, which is  
12 comparable to the germicidal lamps.

13 Notably, the UV content in these lamps is much higher in comparison to that of  
14 the Vortek lamp. Vortek estimate is  $T \sim 3800\text{K}$  and about 1.5% in UVB&C, while the  
15 lamp of figure 1b is  $T \sim 8000\text{K}$  about 9% in UVB&C. Assuming an overall efficiency of  
16 50%, the result is about 5% UVB&C efficiency.

17 The following analysis relates to a high-pressure xenon (Xe) lamp. For a 20 kW xenon  
18 short arc, the peak blackbody emission is about 660 nm and corresponding to a  
19 temperature of about 4500K. The spectrum is quasi-blackbody, with an estimated  
20 emissivity of between about 60 to about 80%. The UVB&C emission of this lamp is  
21 about 3% of the total but appears to have a glass cut off at about 240 nm; as such, the  
22 emissivity may be higher, about 6%. For a total emission efficiency of 70%, the  
23 corresponding UVB&C is between about 2% to about 4%.

1 The following analysis is associated with a high-pressure mercury (Hg) lamp,  
2 wherein a short-arc lamp appears to be fairly low pressure as characterized by a line  
3 spectrum. The spectrum representative of a high pressure Hg lamp notably includes a  
4 predominant line at about 254 nm, which is in the well-established UVB&C disinfection  
5 range. Most of the UV appears in the UVA range 300 to 400 nm, which is not useful  
6 according to the prior art systems; surprisingly, this high-pressure lamp is effective when  
7 used in the preferred embodiments according to the present invention. However, the  
8 spectrum is more difficult to quantify than those of lamps set forth in the foregoing, with  
9 an apparent temperature of about 8000K and an emissivity of approximately about 0.1.  
10 Generally, the high pressure lamps will have lower UVB&C efficacy than the low  
11 pressure germicidal lamps, but due to the higher power rating will have much more total  
12 UVB&C emission.

13 Additionally, there exists a commercially available High Power Lamp (HPL) in  
14 this long cylindrical form, made by Fusion Systems, and driven by a RF power source  
15 (rather than DC as most of the rest) that also works effectively with the UV fluid  
16 disinfection system and method according to the present invention. The discharge of this  
17 HPL is electrodeless, and the lamp life is good, approximately 5000 hours. These tubular  
18 lamps are most consistent with axial flow systems and retrofit design configurations for  
19 embodiments of the present invention, or Planar Vertical Riser (PVR) systems. The  
20 parameters for the Compact/Short-arc Lamps (CSL) and Cylindrical Vertical Riser  
21 (CVR) are consistent with the calculations and examples set forth herein.

22 The fundamental physical parameters that control the design for these kinds of  
23 systems are the lamp power per unit length, P/L, the dosing required, D =



5 The LPL, MPL, HPL, and UHPLs generally have the following characteristics:

Lamp type	Power	Length	Power/length
LPL	<300W	~ 50cm	<3 W/cm
MPL	300 to 3000W	~100cm	3 to 30W/cm
HPL	2000 to 6000W	~ 25cm	240W/cm
UHPL	50kW to 1000kW	~ 40cm	1 to 3kW/cm

Nominal values are used for these calculations, realizing that the lamp power/length can be adjusted by the pressure, current (input power), and the like. Because of the large difference in power/length (P/L), these lamps are suitable to be used in very different geometries and are considered to be within the scope and contemplation of various embodiments constructed, set forth, and taught consistent with and according to the present invention.

40

41

1 wider. At this point, it is assumed that the upper limit is to the flow cell width,  
2 approximately a few meters.

3 The disinfection dosage,  $D = \text{Energy/volume} = E/V$  varies from between about 50  
4 J/liter to about 500 J/liter. The three parameters  $T$ ,  $P/L$ , and  $D$  control the possible and/or  
5 practical flow geometries according to the following equation:

6  $(P/L)/w/d = E/V/T = D/T$

7

8 Correspondingly, the flow channel width  $[w]$  is set forth as follows:

9  $w = (P/L) * T / (D * d) = (P/L) * T / (D * d)$

10  $w = [P/L (W/cm) * T(sec)] / [D (J/l) * d(cm)] * [1000 \text{ cm}^3/\text{liter}]$

11

12 Analysis for the case for a 10-second water dwell (flow velocity  $\sim 1$  cm/s) in the  
13 irradiated volume follows.

14 For selected four lamp types and selected four water quality levels, the results are  
15 approximately:

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**TABLE 3**  
**FLOW CELL WIDTH FOR VARIOUS TYPES OF WATER**  
**10 SECOND DWELL**  
**AND LAMPS TYPES**  
**(cm)**

Lamp type V	Dose (J/l)				
	50	100	200	500	1000
LPL 2W/cm	40	20	10	4	2
MPL 20 W/cm	400	200	100	40	20
HPL 200W/cm	4000	2000	1000	400	200
UHPL 2000W/cm	40000	20000	10000	4000	2000

For the LPL, the cell widths are reasonable, except perhaps for the highest dosage water. So a single LPL could be used for water treatment with a reasonable flow cell width as long as the water is reasonable pure. The LPL systems that have been deployed, the dosage is always under 100 J/l, so these lamps should be appropriate for small flow cells and low volumetric flow rates unless many of them are used. One way to get higher P/L for higher dosage water using LPLs is to use more lamps per cell. The use of a few lamps oriented in a half star pattern would allow these low P/L lamps to treat more water in a larger cell. Another way to use LPLs with the higher dosage water would be to reduce the flow velocity (increase the dwell time, see Table 3).

For the MPL the cell widths are larger, allowing higher volumetric flow rates. For example, a 200J/l system with a 20W/cm lamp would have a 2 kW lamp, and cell length and width of 100 cm. The MPL seems to be suitable for most water types at 10-

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2 that case, the flow speed could be increased (decrease the dwell time, see Table 5)

4 second dwell time, and is more suited to shorter dwell time processing (see Table 5).

8 Planar Vertical Riser System, a preferred embodiment according to the present invention.

2 velocity):

(cm)

Lamp type V	Dose (J/l)				
	50	100	200	500	1000
LPL 2W/cm	4	2	1	0.4	2
MPL 20 W/cm	40	20	10	4	20
HPL 200W/cm	400	200	100	40	200
UHPL 2000W/cm	4000	20000	1000	400	2000

19 dosage water. A MPL system is particularly effective for the lower dose water, and for

1 the higher dose water by using a few of the medium power lamps, and a somewhat wider  
2 cell. The HPL is now well suited to the flow channel size, except for the lowest dose  
3 water, where the dwell time would need to be reduced even further. The UHPL is  
4 appropriately used for large flow cells, provided that the dwell time is reduced  
5 respectively. For the highest dose water, the flow cells are of a practical size to work  
6 with a vertical riser system as shown in Figure 2, provided the light is allowed to diverge  
7 considerably, and subsecond dwell times are permissible, such as at the interface plate  
8 and associated UV dose zone.

9 As another illustration, consider the flow cell sizes for longer dwell water  
10 processing shown in Table 5.

11 **TABLE 5**  
12 **FLOW CELL WIDTH FOR VARIOUS TYPES OF WATER**  
13 **100 SECOND DWELL**  
14 **AND LAMPS TYPES**  
15 **(cm)**

Lamp type V	Dose (J/l)				
	50	100	200	500	1000
LPL 2W/cm	400	200	100	40	2
MPL 20 W/cm	4000	2000	1000	400	20
HPL 200W/cm	40000	20000	10000	4000	200
UHPL 2000W/cm	400000	200000	100000	40000	2000

16  
17 With a 100 second dwell, the cell widths for all the higher power types of lamps are not  
18 necessarily the most practical design selection, although still functional

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1 As the dwell time changes, the flexibility of system configuration according to the  
2 present invention permits that various tubular lamps can be used to process differing  
3 water types or fluids having various characteristics with reasonable flow cell cross-  
4 sections. The UHPLs can process all 4 water types (from between about 50 J/l to about  
5 500 J/l) and at dwell time less than 1 second, as appropriate for a given fluid treatment  
6 system. HPLs can process water at dwell times around 1 second. MPLs can be used to  
7 process water with between about 1 to a bout 10-second dwell, with the longer dwell time  
8 being used for highest dosage and the shorter dwell time used for the lower dosage water.  
9 Additionally, LPLs are capable of processing the lower dosage water with about 10  
10 second dwell and the higher dosage water with a 100 second dwell. A germicidal lamp  
11 system can be used for the longer dwell times, where the flow cell cross-section becomes  
12 small requiring different optical demagnification.

13 The following section sets forth selected particular design examples for particular  
14 water processing applications.

15 **DESIGN EXAMPLES:**

16 This section outlines a few design examples, not necessarily optimized, but illustrative of  
17 what can be done for a UV fluid disinfection system and method, wherein the fluid is  
18 water. These design examples include:

19 Laboratory effluent purifier

20 Home effluent purifier

21 Housing complex effluent purifier

22 Township effluent purifier

23 City effluent purifier



1 desirable to provide an indication when the lamp needs to be replaced or when other  
2 service to the system is needed or suggested.

3 Since the water demand is relatively low and the cell water flow rate is relatively  
4 high by comparison, the dwell could be increased whereby the lamp operates part of the  
5 time or intermittently, either by sensing control or by timer. This intermittent-type  
6 system arrangement beneficially extends the lamp life thereby providing a longer  
7 replacement time or lamp life cycle. Since the lamp life is degraded by turning it off and  
8 on, the system can be constructed and configured to allow the reservoir to be significantly  
9 depleted before restarting the lamp (e.g., where a sewage reservoir or tank is used, the  
10 lamp activity can be controlled, preprogrammed, and otherwise regulated to correspond  
11 to the tank water size and water level. Depending on the size of the reservoir, and the  
12 number of people using the system (as measured in discharged or used gallons/day), the  
13 lamp is arranged, configured, and programmed to run intermittently, e.g., for an hour or  
14 so per day. In this way, a lamp continuous operation life of about a month could be  
15 extended to perhaps a year, depending upon the particular characteristics and  
16 specifications of the system, including water characteristics.

17 **Housing complex effluent purifier (multiple mercury lamps)**

18 Mercury Lamp power approximately about 3 kW with approximately about  
19 30,000 gpd. Six (6) Lamps at about 500 W, Flow cell about 100 cm long by about 20 cm  
20 diameter. This design would be similar to the Home water purifier set forth in the  
21 foregoing, except that it would use multiple lamps to accommodate the increased effluent  
22 and use and to ensure operation in the event of a lamp failure. In this embodiment, the  
23 lamps are constructed and controlled to run all of the time, and be replaced on a regular



**SECRET**

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lamps required, depending on the fluid characteristics and flow rates desired. Thus, the UV disinfectant system according to the present invention provides efficient and effective treatment of fluid, particularly water in wastewater treatment and other industrial applications.

The present invention requires some pretreatment of the wastewater in cases of wastewater with high turbidity prior to exposure to UV dose zones of the present invention. Traditional means for reducing turbidity including, but not limited to, filtration, dilution, reverse osmosis and chemical treatment may be advantageously employed to increase the UV efficacy of the system according to the present invention. However, certain aspects of the preferred embodiment allow it to more easily handle high turbidity fluids than the prior art.

The interface plate may induce turbulence or cause fluid cascade with a non-planar surface, stair-step surface, downwardly sloping surface, or other the like. The induction of turbulence is particularly advantageous when the fluid is turbid. Turbidity, which is the state of water when it is cloudy from having sediment stirred up, interferes with the transmission of UV energy and decreases the disinfection efficiency of the UV light disinfection system. Thus, turbulence, by inducing rotation in the particle, causes all aspects of a particle to be exposed to the UV light. Additionally, the photocatalytic properties of the system reduce turbidity by degrading the compounds or particles responsible for the turbidity. Furthermore, the reflective aspects of the surfaces of the system enhance the efficacy of the system when operated under turbid conditions because the UV light can strike the various aspects of a particle with the need for the particle to be rotating, thus overcoming the opacity of the particle. Another aspect that enhances



1 Certain modifications and improvements will occur to those skilled in the art upon  
2 a reading of the foregoing description. By way of example, various optical components  
3 are used depending upon the particular UV light source or lamp selection for a given  
4 system. Also, a plurality of UV light source systems, either planar horizontal or retrofit  
5 configurations and/or cylindrical vertical riser configurations, may be combined and  
6 arranged in series to increase the flow rates for which effective UV disinfection of the  
7 fluid occurs. Moreover, a wide range of fluid applications are contemplated within the  
8 scope of the present invention, including application of the UV fluid disinfectant system  
9 and method to wastewater, commercial and industrial wastewater, agricultural sludge and  
10 other waste and wastewater, biomedical and bodily fluids, fluid contaminants influents,  
11 and effluents, and the like are contemplated applications for the present invention,  
12 without substantial departure from the embodiments and teachings contained within this  
13 specification. Additionally, surface treatment, including non-planar surfaces, for UV  
14 disinfection of microorganisms thereon are contemplated applications properly  
15 considered within the scope of the present invention. All modifications and  
16 improvements have been deleted herein for the sake of conciseness and readability but  
17 are properly within the scope of the following claims.

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